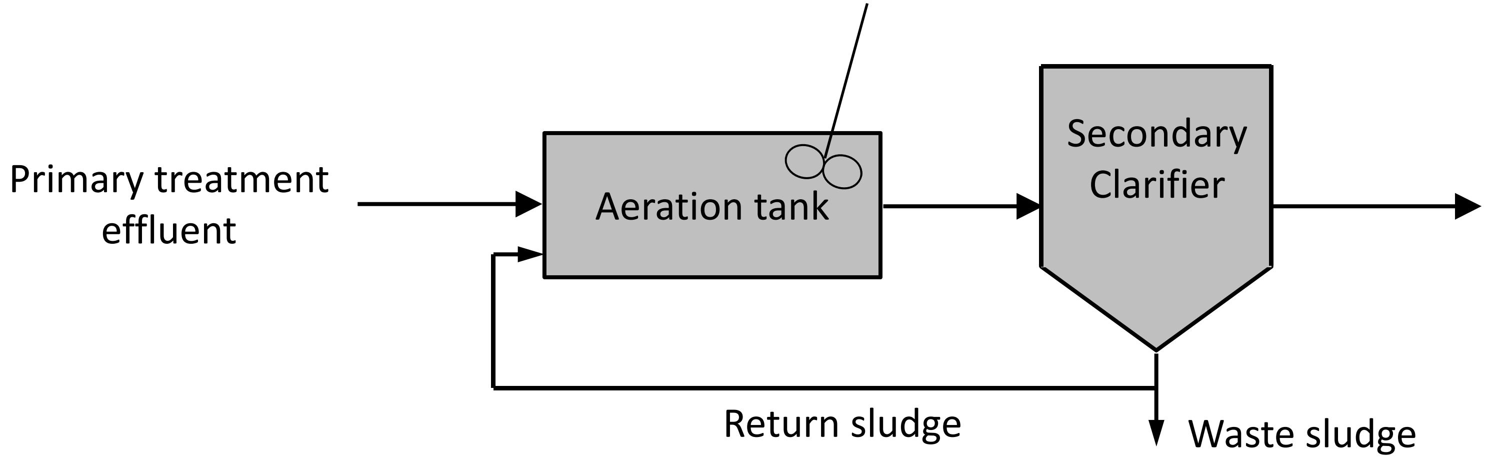
Wastewater treatment II

Today's lecture

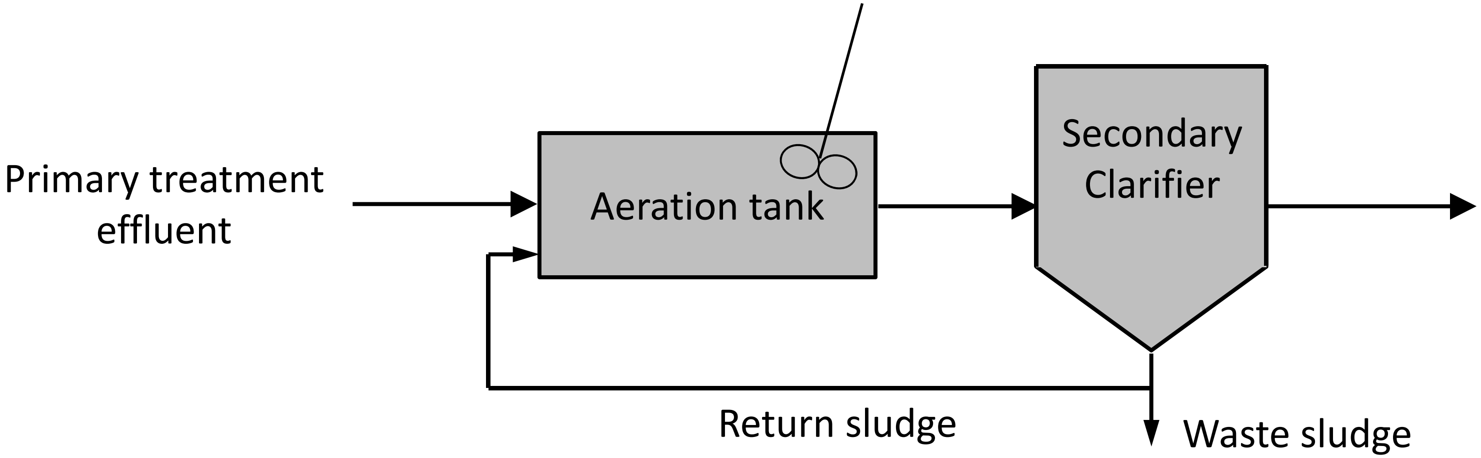
- Overview of activated sludge process
- Mean cell residence time, MLSS, MLVSS
- Analysis of activated sludge process
- Tertiary treatment
- Sludge treatment and disposal
- Wastewater as a resource

Activated sludge process



- A biological wastewater treatment technique using suspended microorganisms (dispersed growth)
- Aeration tank: a mixture of wastewater and microorganisms is agitated and aerated
- Wastewater BOD is removed by active microorganisms

Activated sludge process



- Secondary clarifier: the microorganisms (also called biosolids or sludge) are separated from water by gravity
- Most of the settled sludge is returned to the aeration tank (Why? - We need a high population of microorganisms)
- A fraction of the settled sludge is wasted (Why? – microorganisms grow!)

Mean cell residence time

- Recall hydraulic detention time

  t_0 = the time that fluid elements stay in the system

  $= V/Q$

- Mean cell residence time (or solids retention time)

  θ_c = the time that <u>microorganisms</u> stay in the system

- $t_0 \neq \theta_c$ if sludge is returned to the aeration tank (Why??)

Suspended solids in “mixed liquor”

- The mixture of microorganisms and wastewater in the aeration tank is called “mixed liquor”

- Mixed liquor suspended solids (**MLSS**)
  - A measure of the amount of all suspended solids

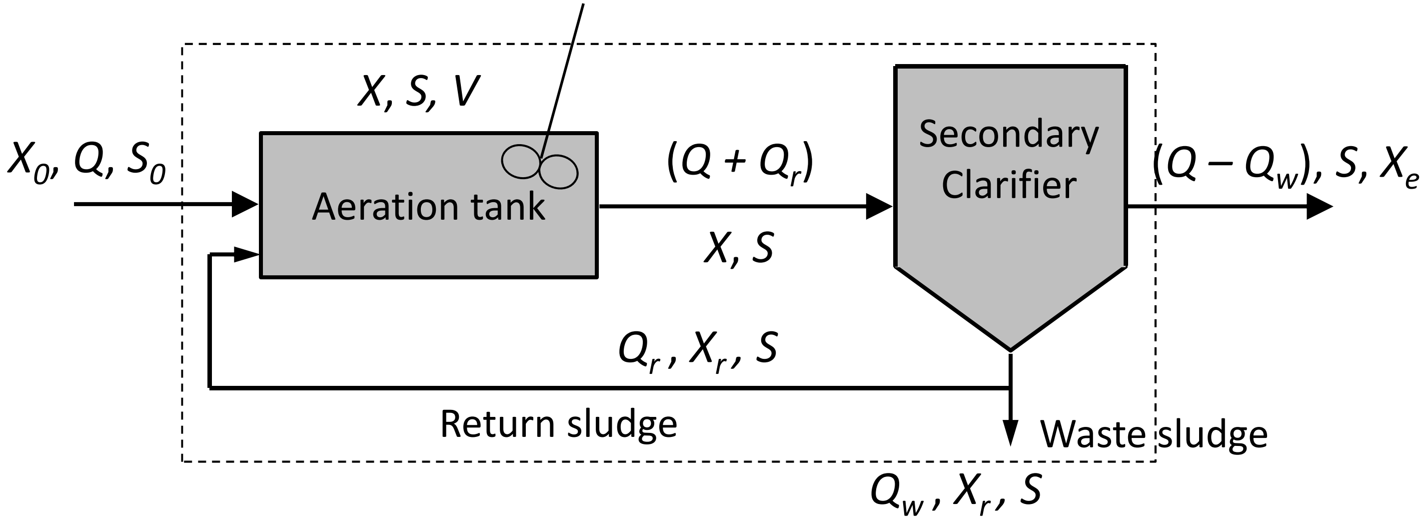
- Mixed liquor volatile suspended solids (**MLVSS**)
  - A measure of the amount of microorganisms
  - Microorganisms are suspended solids which volatilize at 500°C

Analyzing activated sludge process

- Let's analyze the activated sludge process using two basic knowledge:
  - Monod kinetics (the reaction)
  - The system configuration (mass balance)

- We have two substances to analyze:
  - BOD (=substrate=food): the performance of the activated sludge process to treat wastewater
  - Microorganisms (=MLVSS): those that consume BOD; also related to sludge production

Analyzing activated sludge process



X, X_e, X_r: MLVSS concentrations in aeration tank, effluent, and return sludge

Assumption:

i) Steady-state

ii) The aeration tank is a CMFR

iii) All reactions occur in the aeration tank

Analyzing activated sludge process

- Mass balance for substrate:

$$QS_0 - V\frac{\mu_m SX}{Y(K_s + S)} = (Q - Q_w)S + Q_w S$$

- Mass balance for microorganisms:

$$QX_0 + V\left(\frac{\mu_m SX}{K_s + S} - k_d X\right) = (Q - Q_w)X_e + Q_w X_r$$

Analyzing activated sludge process

Additional assumption: The influent and effluent MLVSS is negligible

- Mass balance for microorganisms

$$QX_0 + V\left(\frac{\mu_m SX}{(K_s + S)} - k_d X\right) = (Q - Q_w)X_e + Q_w X_r$$

Analyzing activated sludge process

With some math, we get:

$$\frac{Q_w X_r}{VX} = \frac{Q}{V}\frac{\mathrm{Y}}{X}(S_0 - S) - k_d$$

When the effluent MLVSS is negligible, we find:

$$\theta_c = \frac{MLVSS\ in\ the\ aeration\ tank}{MLVSS\ mass\ flow\ out\ of\ the\ system} = \frac{VX}{Q_w X_r}$$

Analyzing activated sludge process

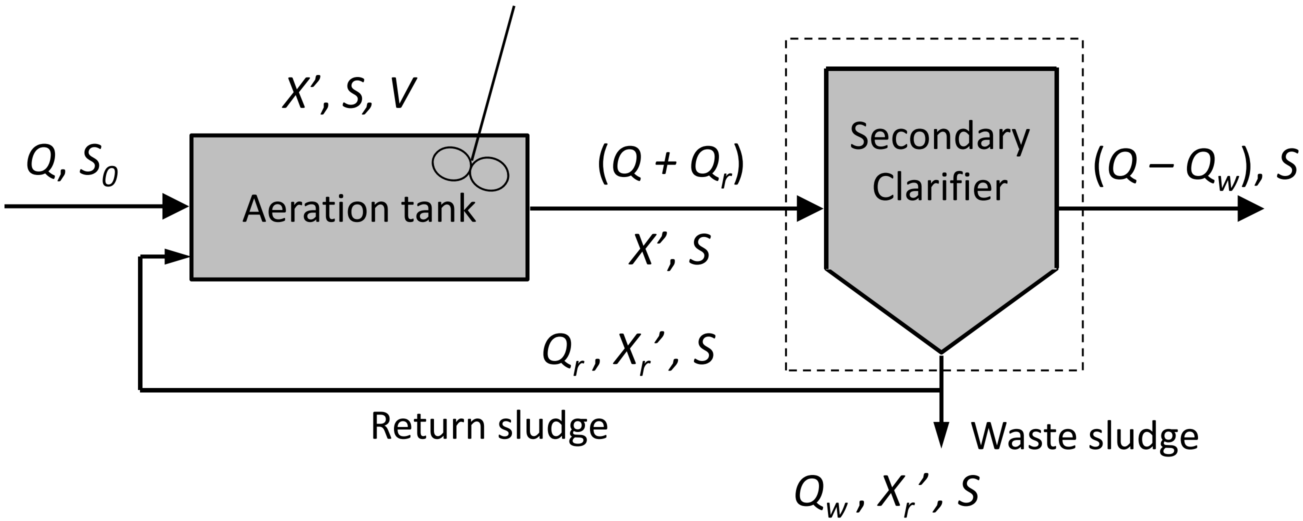
Solutions:

$$S = \frac{K_s(1 + k_d\theta_c)}{\theta_c(\mu_m - k_d) - 1} \qquad X = \frac{\theta_c Y(S_0 - S)}{t_0(1 + k_d\theta_c)}$$

- Mean cell residence time, θ_c, is a key design and operation parameter
- The effluent substrate concentration, *S*, is independent of the influent substrate concentration, S_0
- Higher S_0 → higher MLVSS in the aeration tank → more substrate biodegradation → same *S*

Sludge return

- Goal: to maintain a sufficient concentration of activated sludge (=microorganisms) in the aeration tank
- Mass balance for **MLSS** in the **secondary clarifier** (neglect effluent MLSS)



X', X_r': **MLSS** concentrations in aeration tank and return sludge

Sludge return

- The return sludge flow rate, Q_r, to achieve the MLSS concentration in the aeration tank, X':

$$Q_r = \frac{QX' - Q_w X_r{}'}{X_r' - X'}$$

This solution is under assumption that the effluent MLSS is negligible

(We will keep this assumption for this class, but it is not always true!)

Tertiary (advanced) treatment

- Goal: to improve the quality of the secondary treatment effluent
- Many of the Korean wastewater treatment plants now have advanced treatment process
- Further BOD and SS removal, nutrient removal, TDS removal, or the removal of refractory organic compounds
- Different processes can be used depending on the major target

Sludge treatment

- Sources of solid waste from wastewater treatment
  - Grit chamber: “grits” are inert and water can be easily removed → truck directly to landfill
  - Primary and secondary treatment
    - Produces waste called “sludge”
    - High organic content → rapidly becomes anaerobic and putrefies
    - 3-8% solids for primary sludge & 0.5-2% solids for secondary sludge
  - Tertiary treatment: variable characteristics

Sludge treatment processes

- **Thickening**: separating as much as water possible from the raw sludge by gravity or flotation
- **Stabilization**: converting the organic solids to more inert forms
- **Conditioning**: treating the sludge with chemicals or heat so that the water can be readily separated
- **Dewatering**: separating water by vacuum, pressure, or drying
- **Reduction**: further reducing the solids and water when needed (ex: incineration)

Sludge disposal

- **Land spreading:** can use nutrients and water in the sludge, but pathogen & heavy metal problem
- **Ocean disposal**: simple & easy, but not environmentally-friendly, now prohibited in Korea
- **Landfilling**: simple & easy, but takes a lot of landfill space
- **Composting**: use sludge as a valuable resource – but not well accepted by consumers

Wastewater as a resource

- A new paradigm: wastewater is not a WASTE, but a valuable RESOURCE
- Wastewater = water + nutrients + carbon (energy)
- Water reuse
  – Non-potable reuse: cooling water, irrigation, recreational use
  – Potable reuse: direct/indirect
- Wastewater as a nutrient source
  – Sludge spreading to agricultural sites
  – Sludge composting → use as fertilizers

Wastewater as a resource

- Wastewater as an energy source
  - Wastewater treatment is a high energy process: accounts for 2-5% of the national energy consumption
  - Make the process "energy positive" → lots of energy savings!
  - Several ways to use energy in wastewater
    - CH_4 gas production from wastewater
    - Electricity generation from wastewater
    - Using heat value of wastewater

Reading assignment

Textbook Ch 11 p. 538-554, 562-571